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VERIFICATION OF TRANSLATION

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Date


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APPLICATION FOR UNITED STATES LETTERS PATENT

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INVENTION: OPTICAL WAVELENGTH
 MULTIPLEX ACCESS SYSTEM

S P E C I F I C A T I O N

DESCRIPTION

OPTICAL WAVELENGTH MULTIPLEX ACCESS SYSTEM

5 TECHNICAL FIELD

The present invention relates to an optical wavelength division multiplexing access system for bidirectional transmission of optical signals between a center node (OSU) and a plurality of optical network units (ONUs).

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BACKGROUND ART

In Fig. 1 is shown the configuration of a conventional optical wavelength division multiplexing access system.

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This configuration is disclosed in "A WDM-based optical access network for wide-area gigabit access services", J. Kani et al., IEEE Communication Magazine, vol. 41, issue 2, S43-S48, February 2003 (document 1). The optical wavelength division multiplexing access system comprises:

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a center node (OSU) 50, a wavelength multiplexing/demultiplexing device (herein after W-MULDEM) 60 and a plurality of optical network units (ONU) 70-1 to 70-n. A multiplexing section between the OSU 50 and the W-MULDEM unit 60 is established by extending a downstream optical fiber 1d, for transmitting downstream optical signals from the OSU to the individual ONUs, and an upstream optical fiber 1u, for transmitting upstream optical signals from the individual ONUs to the OSU. Access

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sections between the ONUs 70-1 to 70-n and the W-MULDEM unit 60 are established by extending downstream optical fibers 2d-1 to 2d-n, for transmitting downstream optical signals to the individual ONUs, and upstream optical fibers 2u-1 to 2u-n, for transmitting upstream optical signals from the individual ONUs.

In this configuration, one wavelength band λ_d is allocated for downstream optical signals from the OSU to the ONUs, and one wavelength band λ_u ($\neq \lambda_d$) is allocated for upstream optical signals from the ONUs to the OSU.

Wavelengths λ_{d1} to λ_{dn} , in the wavelength band λ_d , and wavelengths λ_{u1} to λ_{un} , in the wavelength band λ_u , are allocated for the individual ONUs. Further, an arrayed waveguide grating (AWG) is employed as W-MULDEM means for multiplexing or demultiplexing optical signals having individual wavelengths.

Optical transmitter/receiver 51-1 to 51-n of the OSU transmit downstream optical signals having wavelengths λ_{d1} to λ_{dn} , in the wavelength band λ_d , to the individual ONUs. A downstream AWG 52 multiplexes the downstream optical signals. An optical carrier supply module (OCSM) 53 for an upstream signal collectively oscillates optical carriers that are used for upstream signals and have wavelengths λ_{u1} to λ_{un} , in the wavelength band λ_u , that are to be transmitted to the individual ONUs. A WDM coupler 54 multiplexes the downstream optical signals and the optical carriers for upstream signals and transmits the

obtained signals to the W-MULDEM unit 60 through the downstream optical fiber 1d.

In the W-MULDEM unit 60, a WDM coupler 61 demultiplexes the downstream optical signals having the wavelengths λ_d from an optical carrier for an upstream signal having the wavelength λ_u . A downstream AWG 62 demultiplexes the downstream optical signals having the wavelengths λ_{d1} to λ_{dn} , and an upstream signal optical carrier AWG 63 demultiplexes the optical carriers for upstream signals having wavelengths λ_{u1} to λ_{un} . WDM couplers 64-1 to 64-n perform wavelength division multiplexing for the respective downstream optical signals having wavelengths λ_{d1} to λ_{dn} , which are to be transmitted to the individual ONUs, and the optical carriers for upstream signals having wavelengths λ_{u1} to λ_{un} . The resultant downstream optical signals and the optical carriers for upstream signals are transmitted to the corresponding ONUs 70-1 to 70-n along the downstream optical fiber 2d.

An optical transmission/reception unit 71 in the ONU 70-1 demultiplexes a downstream optical signal having the wavelength λ_{d1} from an optical carrier for an upstream signal having the wavelength λ_{u1} , and receives the downstream optical signal having the wavelength λ_{d1} . The optical transmission/reception unit 71 also modulates an optical carrier for an upstream signal having the wavelength λ_{u1} , and transmits the modulated signal as a return upstream optical signal to the W-MULDEM unit 60 through the upstream

optical fiber 2u. The other ONUs perform the same processing. An upstream AWG 65 in the W-MULDEM unit 60 multiplexes the upstream optical signals, having wavelengths λ_{u1} to λ_{un} , that are transmitted by the individual ONUs, and transmits the obtained signals to the OSU 50 through the upstream optical fiber 1u. The upstream optical signal is demultiplexed by an upstream AWG 55 of the OSU 50, and the obtained signals are transmitted to the optical transmitter/receiver 51-1 to 51-n that correspond to the ONUs.

As is shown in Fig. 1, the wavelength band λ_d (wavelengths λ_{d1} to λ_{dn}) for the downstream optical signal and the wavelength band λ_u (wavelengths λ_{u1} to λ_{un}) for the optical carrier for the upstream signal are arranged so that they do not overlap along the wavelength axis (or along the optical frequency axis; optical frequency = light velocity/wavelength). An AWG, a property of which is that wavelengths at an FSR (Free Spectrum Range) interval are multiplexed or demultiplexed at the same time, is employed as the downstream AWG 62 and the optical carrier AWG 63 for upstream signals that are provided for the W-MULDEM unit 60. When the wavelength interval for the downstream optical signal (e.g., λ_{d1}) and the optical carrier (e.g., λ_{u1}) for the upstream signal are designated to be the FSR, the signal and the carrier can be routed to the same port by the AWG, so that only one AWG is required. In this case, the WDM couplers 61 and 64-1 to 64-n are eliminated.

When an obstacle, such as the severing of a fiber, has occurred at the multiplexing section between the OSU 50 and the W-MULDEM unit 60, communication with all ONUs is disabled. Therefore, it is preferable that, in order to obtain a dual multiplexing section, an optical fiber for current use and a redundant optical fiber be provided, and a function for switching to the redundant optical fiber be furnished for the OSU 50 and the W-MULDEM unit 60.

In Fig. 2 is shown the configuration of a common dual system. Opposite transmission devices 81 and 82 are connected via a current-use optical fiber 83 and a redundant optical fiber 84. An optical signal, transmitted by an optical transmission/reception unit 85 of the transmission device 81, is branched, to obtain two signals, by a photocoupler 86-1, and the branched signals are transmitted to the transmission device 82 along a current-use optical fiber 83 and a redundant optical fiber 84. Then, one of the optical fibers (the current-use optical fiber in this case) is selected at an optical switch 87-1 for the transmission device 82, and the signal is received by an optical transmission/reception unit 88. The same process is performed for a signal transmission in the opposite direction.

When the multiplexing section between the OSU 50 and the W-MULDEM unit 60 is to be doubled by using the switching method that employs the optical switch shown in Fig. 2, a dynamic function (optical switch) is required for the

W-MULDEM unit 60, which originally does not need such a dynamic function. Accordingly, new control means is required to control the switching in the W-MULDEM unit 60, and the entire system becomes complicated.

5 It is one objective of the present invention to obtain a dual multiplexing section between an OSU and a W-MULDEM unit without adding a dynamic function, such as an optical switch, to the W-MULDEM unit.

10 DISCLOSURE OF THE INVENTION

 To achieve this objective, according to a first embodiment of the present invention, an optical wavelength division multiplexing access system, whereby a center node (OSU) and n optical network units (ONUs) are arranged by
15 using a W-MULDEM unit, whereby a multiplexing section between the OSU and the W-MULDEM unit is established by extending a current-use optical fiber and a redundant optical fiber and access sections between the W-MULDEM unit and the individual ONUs are established by the extension
20 of optical fibers, whereby downstream optical signals from the OSU to the ONUs and upstream optical signals from the ONUs to the OSU are multiplexed using wavelengths that are allocated to individual ONUs and the resultant signals are transmitted across the multiplexing section, and
25 whereby the W-MULDEM unit performs wavelength multiplexing or wavelength demultiplexing for the upstream or downstream optical signals to provide bidirectional transmission,

is characterized in that:

the OSU includes transmission means for multiplexing downstream optical signals having wavelengths λ_{d1} to λ_{dn} that correspond to the ONUs and that are to be transmitted to the ONUs along the current-use optical fiber, for multiplexing downstream optical signals having wavelengths $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda$ that correspond to the ONUs and that are to be transmitted to the ONUs along the redundant optical fiber, and for selecting either the current-use optical fiber or the redundant optical fiber for use for transmission, and reception means for receiving upstream optical signals having wavelengths λ_{u1} to λ_{un} along the current-use optical fiber or for receiving upstream optical signals having wavelengths $\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ along the redundant optical fiber;

the individual ONUs receive corresponding downstream optical signals having wavelengths λ_{d1} to λ_{dn} or corresponding downstream optical signals having wavelengths $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda$, which are received along the optical fibers extended across the access sections, the individual ONUs transmit, to the optical fibers extended across the access sections, corresponding upstream optical signals that have wavelengths λ_{u1} to λ_{un} and are to be transmitted along the current-use optical fiber extended across the multiplexing section, or corresponding upstream optical signals that have wavelengths $\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ and are to be transmitted along the redundant optical fiber;

the W-MULDEM unit includes an array waveguide diffraction grating (AWG) having two ports, which are to be respectively connected to the current-use optical fiber and the redundant optical fiber, and n ports, which are to be connected to optical fibers corresponding to the ONUs;

the W-MULDEM unit demultiplexes to the ports corresponding to the ONUs the downstream optical signals that have wavelengths λ_{d1} to λ_{dn} and are received along the current-use optical fiber, or the downstream optical signals that have wavelengths $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda$ and are received along the redundant optical fiber, or multiplexes, to the port corresponding to the current-use optical fiber or the redundant optical fiber, the upstream optical signals that have wavelengths λ_{u1} to λ_{un} or wavelengths $\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ and that are received along the optical fibers corresponding to the ONUs; and

a wavelength difference between the downstream optical signal and the upstream optical signal corresponding to each of the ONUs is integer times a free spectrum range (FSR) of the AWG.

According to a second embodiment of the present invention, an optical wavelength division multiplexing access system, whereby a center node (OSU) and n optical network units (ONUs) are arranged through a W-MULDEM unit, whereby a multiplexing section between the OSU and the W-MULDEM unit is established by extending a current-use

downstream optical fiber, a current-use upstream optical fiber, a reserve downstream optical fiber and a reserve upstream optical fiber and access sections between the W-MULDEM unit and the individual ONUs are established by the extension of downstream optical fibers and of upstream optical fibers, whereby downstream optical signals from the OSU to the ONUs and upstream optical signals from the ONUs to the OSU are multiplexed, using wavelengths that are allocated to the individual ONUs, and resultant optical signals are transmitted across the multiplexing section, and whereby the W-MULDEM unit performs either wavelength multiplexing or wavelength division for the upstream or downstream optical signals to provide bidirectional transmission, is characterized in that:

the OSU includes transmission means for multiplexing downstream optical signals having wavelengths λ_{d1} to λ_{dn} that correspond to the ONUs and that are to be transmitted to the ONUs along the current-use downstream optical fiber, for multiplexing downstream optical signals having wavelengths $\lambda_{d1} + \Delta\lambda$ to $\lambda_{dn} + \Delta\lambda$ that correspond to the ONUs and that are to be transmitted to the ONUs along the reserve downstream optical fiber, and for selecting either the current-use downstream optical fiber or the reserve downstream optical fiber used for transmission, and reception means for receiving upstream optical signals having wavelengths λ_{u1} to λ_{un} transmitted along the current-use upstream optical fiber, or for receiving

upstream optical signals having wavelengths $\lambda_{u1} + \Delta\lambda$ to $\lambda_{un} + \Delta\lambda$ transmitted along the reserve upstream optical fiber;

the ONUs receive, along the optical fibers extended
5 across the access sections, corresponding downstream optical signals having wavelengths λ_{d1} to λ_{dn} or corresponding downstream optical signals having wavelengths $\lambda_{d1} + \Delta\lambda$ to $\lambda_{dn} + \Delta\lambda$, the ONUs transmit, to the optical fibers extended across the access sections,
10 corresponding upstream optical signals that have wavelengths λ_{u1} to λ_{un} and that are to be transmitted along the current-use optical fiber extended across the multiplexing section, or corresponding upstream optical signals that have wavelengths $\lambda_{u1} + \Delta\lambda$ to $\lambda_{un} + \Delta\lambda$ and are to
15 be transmitted along the redundant optical fiber;

the W-MULDEM unit includes a downstream array waveguide diffraction grating (AWG) having two ports, which are to be respectively connected to the current-use downstream optical fiber and the reserve downstream optical fiber,
20 and n ports, which are to be connected to optical fibers corresponding to the ONUs, and an upstream array waveguide diffraction grating (upstream AWG) having two ports, which are to be respectively connected to the current-use upstream optical fiber and the reserve upstream optical fiber, and
25 n ports, which are connected to the optical fibers corresponding to the ONUs; and

the W-MULDEM unit demultiplexes to the ports of the

downstream AWG that correspond to the ONUs the downstream optical signals that have wavelengths λ_{d1} to λ_{dn} and are received along the current-use downstream optical fiber, or the downstream optical signals that have wavelengths $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda$ and are received along the reserve downstream optical fiber, or multiplexes, to the port corresponding to the current-use upstream optical fiber or the reserve upstream optical fiber, the upstream optical signals that have wavelengths λ_{u1} to λ_{un} or wavelengths $\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ and that are transmitted to the upstream AWG along the optical fibers corresponding to the ONUs.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the configuration of a conventional optical wavelength division multiplexing access system;

Fig. 2 is a diagram showing the configuration of a common dual system;

Fig. 3 is a diagram showing an optical wavelength division multiplexing access system according to a first embodiment of the present invention;

Figs. 4A and 4B are diagrams showing a first example for wavelength allocation according to the first embodiment;

Figs. 5A and 5B are diagrams showing a second example for wavelength allocation according to the first embodiment;

Fig. 6 is a diagram showing an example current-use and reserve-use switching configuration according to the first embodiment;

5 Fig. 7 is a diagram showing an optical wavelength division multiplexing access system according to a second embodiment of the present invention;

Figs. 8A and 8B are diagrams showing wavelength allocation according to the second embodiment;

10 Fig. 9 is a diagram showing a first example current-use and reserve-use switching configuration according to the second embodiment;

Fig. 10 is a diagram showing a second example current-use and reserve-use switching configuration according to the second embodiment;

15 Fig. 11 is a diagram showing a third example current-use and reserve-use switching configuration according to the second embodiment;

20 Fig. 12 is a diagram showing a fourth example current-use and reserve-use switching configuration according to the second embodiment;

Fig. 13 is a diagram showing an optical wavelength division multiplexing access system according to a third embodiment of the present invention;

25 Figs. 14A to 14C are diagrams showing example wavelength allocations according to the third embodiment;

Figs. 15A to 15C are diagrams showing example wavelength allocations according to a fourth embodiment;

Fig. 16 is a diagram showing an optical wavelength division multiplexing access system according to a fifth embodiment of the present invention;

Fig. 17 is a diagram showing an optical wavelength division multiplexing access system according to a sixth embodiment of the present invention;

Fig. 18 is a diagram showing an optical wavelength division multiplexing access system according to a seventh embodiment of the present invention;

Fig. 19 is a diagram showing an optical wavelength division multiplexing access system according to a ninth embodiment of the present invention;

Fig. 20 is a diagram showing an optical wavelength division multiplexing access system according to a tenth embodiment of the present invention;

Fig. 21 is a diagram showing an optical wavelength division multiplexing access system according to an eleventh embodiment of the present invention; and

Fig. 22 is a diagram showing an optical wavelength division multiplexing access system according to a twelfth embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[First Embodiment]

(Wavelength allocation)

In Fig. 3 is shown an optical wavelength division multiplexing access system according to a first embodiment

of the present invention. The optical wavelength division multiplexing access system for this embodiment comprises a center node (OSU) 10, a W-MULDEM unit 20, and a plurality of optical network units (ONUs) 30-1 to 30-n. The multiplexing section between the OSU 10 and the W-MULDEM unit 20 is established by extension of a current-use optical fiber 101 and a redundant optical fiber 102, for transmitting a downstream optical signal from the OSU 10 to the individual ONUs 30 and upstream optical signals from ONUs 30 to the OSU 10. The access sections between the individual ONUs 30-1 to 30-n and the W-MULDEM unit 20 are established by the extension of optical fibers 103-1 to 103-n, for transmitting a downstream optical signals to the ONUs and upstream optical signals from the ONUs.

The OSU 10 includes: current-use optical transmitter/receiver 11-1w to 11-nw and reserve optical transmitter/receiver 11-1p to 11-np, which correspond to the ONUs; a current-use AWG 12w, which multiplexes downstream optical signals having wavelengths λ_{d1} to λ_{dn} that which have been received from the current-use optical transmitter/receiver 11-1w to 11-nw and transmits the obtained optical signal to the current-use optical fiber 101, or which demultiplexes to the current-use optical transmitter/receiver 11-1w to 11-nw upstream optical signals having wavelengths λ_{u1} to λ_{un} that have been received along the current-use optical fiber 101; and a reserve AWG 12p, which multiplexes downstream optical signals

having wavelengths $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda$ that have been received from the reserve optical transmitter/receiver 11-1p to 11-np and transmits the obtained optical signal to the redundant optical fiber 102, or which demultiplexes to the reserve optical transmitter/receiver 11-1p to 11-np upstream optical signals having wavelengths $\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ that have been received over the redundant optical fiber 102.

Optical transmission/reception circuits 31 of the individual ONUs 30-1 to 30-n receive, along the optical fibers 103 extended at the access sections, either downstream optical signals having wavelengths λ_{d1} to λ_{dn} , or downstream optical signals having wavelengths $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda$. Further, for the transmission of an upstream optical signal along the current-use optical fiber 101 at the multiplexing section, the optical transmission/reception circuits 31 select upstream optical signals having wavelengths λ_{u1} to λ_{un} , or for the transmission of an upstream optical signal along the reserve optical fiber 102, select upstream optical signals having wavelengths $\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ and transmit the selected upstream optical signals to the optical fibers 103 at the access sections.

The W-MULDEM unit 20 is constituted by a single AWG 21. The AWG 21 includes: two ports that are respectively connected to the current-use optical fiber 101 and the redundant optical fiber 103 that extend across the

multiplexing section; n ports #1 to # n that are connected to the optical fibers 103-1 to 103- n that extend across the access section and correspond to the ONUs. The downstream optical signals having wavelengths λ_{d1} to λ_{dn} that have been received along the current-optical fiber to the port W, or the downstream optical signals having wavelengths $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda$ that have been received along the redundant optical fiber to the port P, are routed to the ports #1 to # n that correspond to the ONUs. Furthermore, the upstream optical signals having wavelengths λ_{u1} to λ_{un} , are received at the ports #1 to # n along the optical fibers 103 that correspond to the ONUs, and are merged at the port W corresponding to the current-use optical fiber 101. The upstream optical signals having wavelengths $\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ are merged at the port P corresponding to the redundant optical fiber 102.

In Fig. 4A is shown an example wavelength allocation for the ports W and P and the ports #1 to # n of the AWG 21. For example, the downstream optical signal having wavelength λ_{d1} , which is received at the port W along the current-use optical fiber 101, and the downstream optical signal having wavelength $\lambda_{d1}+\Delta\lambda$, which is received along the redundant optical fiber 102, are output to the port #1. Further, the upstream optical signal having wavelength λ_{u1} , or the upstream optical signal having wavelength $\lambda_{u1}+\Delta\lambda$, which is received at the port #1 from the ONU 30-1, is output to the port W and port P.

For this process, the free spectrum range (FSR) of the AWG should be taken into account for the allocation of the wavelengths. The diffraction order is an arbitrary integer, and a plurality of center wavelengths are present for one AWG. A band that can be used by one AWG without being overlapping is called an FSR, and the property that is repeated for each FSR is employed. That is, as is shown in Fig. 4B, a difference between the wavelengths λ_{d1} and λ_{u1} is defined as integer times (aFSR) the FSR of the AWG 21, and the ports W and P are provided at locations consonant with a difference $\Delta\lambda$ between the wavelengths for current use and reserve use. It should be noted that the difference $\Delta\lambda$ between the wavelengths for current use and reserve use may be either positive or negative, and mFSR (m is an integer) may be added to the difference.

In this specification, the wavelength λ can be replaced with a frequency f . The wavelength difference $\Delta\lambda$ can not exactly be replaced with a frequency difference Δf , because the ratio of the wavelength difference $\Delta\lambda$ to the frequency difference Δf is changed when a wavelength differs. However, it will be apparent to one having ordinary skill in the art that the replacement of the wavelength difference $\Delta\lambda$ with the frequency difference Δf is also included within the scope of the present invention.

In Fig. 5A is shown another example wavelength allocation. The wavelength interval between the wavelengths λ_{d1} , λ_{d2} , . . . and λ_{dn} of the current-use

downstream optical signals, which are demultiplexed by the AWG 21, and the wavelength interval between the wavelengths λ_{u1} , λ_{u2} , . . . and λ_{un} of the current-use upstream optical signals, are adjusted to equal the difference $\Delta\lambda$ between the wavelengths for the current use and the reverse use. As a result, the wavelengths of the reserve downstream optical signals are λ_{d2} , λ_{d3} , . . . and λ_{dn+1} , and the wavelengths of the reserve upstream optical signals are λ_{u2} , λ_{u3} , . . . and λ_{un+1} . As is shown in Fig. 5B, when $\lambda_{dn} + 1 = \lambda_{d1} + \text{FSR}$ is established, the wavelength λ_{dn+1} of the reserve downstream optical signal that corresponds to the ONU 30-n can be set as λ_{d1} . Similarly, when $\lambda_{un} + 1 = \lambda_{u1} + \text{FSR}$ is established, the wavelength λ_{un+1} of the reserve upstream optical signal that corresponds to the OSU 30-n can be set as λ_{u1} .

According to this embodiment, since the wavelength difference between the downstream optical signal and the upstream optical signal is defined as the aFSR, and since the difference between the wavelengths for current use and reserve use is defined as $\Delta\lambda (+ m\text{FSR})$, a dual optical fiber structure can be obtained at the multiplexing section, and the current use system and the reserve use system can be alternately selected, passively, by a single AWG. That is, for the transmission of the downstream optical signals to the ONUs 30-1 to 30-n along the current-use optical fiber 101, the OSU 10 multiplexes the downstream optical signals having wavelengths λ_{d1} to λ_{dn} and corresponding

to the individual ONUs, and for the transmission along the redundant optical fiber 102, multiplexes the downstream optical signals having wavelengths $\lambda_{d1} + \Delta\lambda$ (or λ_{d2}) to $\lambda_{dn} + \Delta\lambda$ (or λ_{dn+1}) and corresponding to the ONUs. On the other hand, for the transmission of upstream optical signals along the current-use optical fiber 101 at the multiplexing section, the ONUs 30-1 to 30-n can transmit upstream optical signals having wavelengths λ_{u1} to λ_{un} , while for the transmission along the redundant optical fiber 102, they can transmit the upstream optical signals having wavelengths $\lambda_{u1} + \Delta\lambda$ (or λ_{u2}) to $\lambda_{un} + \Delta\lambda$ (or λ_{un+1}). Through this wavelength selection, the W-MULDEM unit 20 can passively select the current use system and the reverse system.

(Current-use and reserve-use switching configuration using optical switches)

An explanation will now be given for means for transmitting or receiving signals by selecting either the current-use optical fiber 101 or the redundant optical fiber 102. In Fig. 6 is shown a current-use and a reserve-use selection configuration according to the first embodiment that employs optical switches.

The OSU 10 also includes: an optical switch 16w, which is used to set ON or OFF the input/output between the current-use optical fiber 101 and the current-use AWG 12w; and an optical switch 16p, which is used to set ON or OFF the input/output between the redundant optical fiber

102 and the reserve AWG 12p. In addition, the OSU 10 includes: a supervisory light source 15, for outputting supervisory light having a wavelength of λ_{s0} to supervise the current-use optical fiber 101, and supervisory light
5 having a wavelength of λ_{s1} to supervise the redundant optical fiber 102; and a supervisory control unit 14, for detecting the supervisory lights having wavelengths λ_{s0} and λ_{s1} after the transmission along the current-use optical fiber 101 and the redundant optical fiber 102 has been completed,
10 and for transmitting a selection signal.

Multiplexing/demultiplexing units 13w and 23w, for multiplexing or demultiplexing wavelength λ_{s0} , are provided for the current-use optical fiber 101, and
multiplexing/demultiplexing units 13p and 23p, for
15 multiplexing or demultiplexing wavelength λ_{s1} , are provided for the redundant optical fiber 102.

The multiplexing/demultiplexing unit 13w (13p) multiplexes the supervisory light, which has wavelength λ_{s0} (λ_{s1}) and is received from the supervisory light source
20 15, and the downstream optical signals that have wavelengths λ_{d1} to λ_{dn} (wavelengths $\lambda_{d1} + \Delta\lambda$ to $\lambda_{dn} + \Delta\lambda$), which are to be transmitted along the current-use optical fiber 101 or the redundant optical fiber 101. The
multiplexing/demultiplexing unit 23w (23p) of the W-MULDEM
25 unit 20 reflects the supervisory light by using, for example, a mirror or a filter, and outputs it again to the current-use optical fiber 101. The multiplexing/demultiplexing unit

13w (13p) extracts only the supervisory light, which it transmits to the supervisory control unit 14.

In this embodiment, when the current-use optical fiber 101 is employed, the optical switch 16w is set to the ON state, while the optical switch 16p is set to the OFF state, and communication between the OSU 10 and the ONUs 30 is performed by using the downstream optical signals having wavelengths λ_{d1} to λ_{dn} and the upstream optical signals having wavelengths $\lambda_{u1} + \Delta\lambda$ to $\lambda_{n} + \Delta\lambda$. When a failure occurs in the current-use optical fiber 101 extending across the multiplexing section, the supervisory control unit 14 transmits a select signal to the optical switches 16w and 16p to set the optical switch 16w to the OFF state and the optical switch 16p to the ON state. As a result, the redundant optical fiber 102 is selected.

Further, when a failure occurs in the current-use transmission/reception units 11-1w to 11-nw of the OSU 10, the states of the optical switches 16w and 16p are changed in accordance with a selection signal received from the supervisory control unit 14, and the reserve optical transmitter/receiver 11-1p to 11-np are selected.

It should be noted that either a configuration wherein either the current-use optical transmitter/receiver 11-1w to 11-nw or the reserve optical transmitter/receiver 11-1p to 11-np are set to the ON state and the others are set to the OFF state, or a configuration wherein an electric signal is changed so it is input/output at the current-use

optical transmitter/receiver 11-1w to 11-nw or at the reserve optical transmitter/receiver 11-1p to 11-np can also be employed.

[Second Embodiment]

5 (Wavelength allocation)

In Fig. 7 is shown an optical wavelength division multiplexing access system according to a second embodiment of the present invention. For the sake of the explanation, the appended portion for wavelength λ is changed; λ_{dw1} to $\lambda_{dwn}/\lambda_{uw1}$ to λ_{uwn} are employed instead of λ_{d1} to $\lambda_{dn}/\lambda_{u1}$ to λ_{un} for the current-use optical signals; and λ_{dpl} to $\lambda_{dpn}/\lambda_{upl}$ to λ_{upn} are employed instead of $\lambda_{d1}+\Delta\lambda$ to $\lambda_{dn}+\Delta\lambda/\lambda_{u1}+\Delta\lambda$ to $\lambda_{un}+\Delta\lambda$ for the reserve optical signals.

According to this embodiment, the optical wavelength division multiplexing access system comprises: a center node (OSU) 10, a W-MULDEM unit 20 and a plurality of optical network units (ONU) 30-1 to 30-n. The multiplexing section between the OSU 10 and the W-MULDEM unit 20 is established by extending a downstream current-use optical fiber 111 and a downstream redundant optical fiber 121, for transmitting downstream optical signals from the OSU to the individual ONUs, and an upstream current-use optical fiber 112 and an upstream redundant optical fiber 122, for transmitting upstream optical signals from the ONUs to the OSU. The access sections between the ONUs 30-1 to 30-n and the W-MULDEM unit 20 are established by extending downstream optical fibers 131-1 to 131-n, for transmitting

downstream optical fibers to the ONUs, and upstream optical fibers 132-1 to 132-n, for transmitting upstream optical signals from the ONUs.

The OSU 10 includes: current-use optical
5 transmitter/receiver 11-1w to 11-nw and reserve optical transmitter/receiver 11-1p to 11-np, which correspond to the individual ONUs 30; a downstream current-use AWG 12dw, which multiplexes the downstream optical signals that have wavelengths λ_{dw1} to λ_{dwn} and have been received from the
10 current-use optical transmitter/receiver 11-1w to 11-nw, and transmits the resultant optical signal to the downstream current-use optical fiber 111; and an upstream current-use AWG 12uw, which demultiplexes to the current-use optical transmitter/receiver 11-1w to 11-nw the upstream optical
15 signals that have wavelengths λ_{uw1} to λ_{uwn} and are received along the upstream current-use optical fiber 112. The OSU 10 further includes: a downstream reserve AWG 12dp, which multiplexes the downstream optical signals that have wavelengths λ_{dp1} to λ_{dpn} and are received from the reserve
20 transmission/reception units 11-1p to 11-np, and transmits the resultant signal to the downstream redundant optical fiber 121; and an upstream reserve AWG 12up, which demultiplexes to the reserve optical transmitter/receiver 11-1p to 11-np the upstream optical signals that have
25 wavelengths λ_{up1} to λ_{upn} and are received along the upstream redundant optical fiber 122.

The OSU 10 also includes: a light source 15, which

outputs a current-use supervisory light having wavelength λ_{s0} that differs from the wavelengths λ_{dw1} to λ_{dwn} and λ_{uw1} to λ_{uwn} , and a reserve supervisory light, which has a wavelength λ_{s1} that differs from the wavelengths λ_{dp1} to λ_{dpn} and λ_{up1} to λ_{upn} ; and a supervisory control unit 14, which detects the supervisory light having wavelengths λ_{s0} and λ_{s1} , after their transmission along the current-use optical fiber and the redundant optical fiber has been completed, and which transmits a select signal.

Means for selecting the downstream current-use optical fiber 111 or the downstream redundant optical fiber 121 for use in transmission can be a configuration wherein, in accordance with a select signal received from the supervisory control unit 14, either the current-use optical transmitter/receiver 11-1w to 11-nw or the reserve optical transmitter/receiver 11-1p to 11-np are set to the ON state and the others are set to the OFF state, or a configuration wherein an electric signal is changed that is to be transmitted to the current-use optical transmitter/receiver 11-1w to 11-nw or to the reserve optical transmitter/receiver 11-1p to 11-np. Further, means for selecting the upstream current-use optical fiber 112 or the upstream redundant optical fiber 122 can be a configuration wherein, in accordance with a select signal received from the supervisory control unit 14, either the current-use optical transmitter/receiver 11-1w to 11-nw or the reserve optical transmitter/receiver 11-1p to 11-np

are set to the ON state and the others are set to the OFF state, or a configuration wherein an electric signal is changed that is to be output by the current-use optical transmitter/receiver 11-1w to 11-nw or to the reserve optical transmitter/receiver 11-1p to 11-np.

Optical transmission/reception circuits 31 of the ONUs 30-1 to 30-n receive, through the downstream optical fibers 131 at the access sections, the downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} or λ_{dp1} to λ_{dpn} .

Further, for the transmission of upstream optical signals along the upstream current-use optical fiber 112 at the multiplexing section, the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} are selected and transmitted to the upstream optical fibers at the access sections, and for the transmission of upstream optical signals along the upstream redundant optical fiber 122, upstream optical signals having wavelengths λ_{up1} to λ_{upn} are selected.

The W-MULDEM unit 20 is constituted by a downstream AWG 22d and an upstream AWG 22u. The downstream AWG 22d includes: two ports, W and P, that are connected to the downstream current-use optical fiber 111 and the downstream redundant optical fiber 121 at the multiplexing section; and n ports #1 to #n, which are connected to the downstream optical fibers 131 at the access sections that correspond to the ONUs. The upstream AWG 22u includes: n ports #1 to #n, which are connected to the upstream optical fibers 132 at the access sections that correspond to the ONUs;

and two ports W and P, which are connected to the upstream current-use optical fiber 112 and the upstream redundant optical fiber 122 at the multiplexing section.

5 The downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} , which are received at the port W of the downstream AWG 22d along the downstream current-use optical fiber 111, or the downstream optical signals having wavelengths λ_{dp1} to λ_{dpn} , which are received at the port P along the downstream redundant optical fiber 112, are
10 branched to the ports #1 to #n that correspond to the ONUs.

On the other hand, the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , which are received at the ports #1 to #n of the upstream AWG 22u along the optical fibers that correspond to the ONUs, are merged at the port W that
15 corresponds to the upstream current-use optical fiber 112, and the upstream optical signals having wavelengths λ_{up1} to λ_{upn} , are merged at the port P that corresponds to the upstream redundant optical fiber 122.

When an optical amplifier is required because the
20 loss, for example, of an optical fiber is increased, an optical fiber may be connected to the downstream current-use (or reserve) optical fiber in order to collectively amplify the downstream optical signals that were multiplexed immediately before they reached the port W (or P) of the
25 AWG 22d. Similarly, for the upstream current-use (or reserve) optical fiber, an optical amplifier may be connected in order to collectively amplify the upstream

optical signals that were multiplexed immediately after they reached the port W (or P) of the AWG 22u.

A multiplexing unit 13dw, for multiplexing the supervisory light having wavelength λ_{s0} and the downstream signal light having wavelengths λ_{dw1} to λ_{dwn} , and a demultiplexing unit 23dw, for demultiplexing the supervisory light having wavelength λ_{s0} from the downstream signal light having wavelengths λ_{dw1} to λ_{dwn} , are provided for the downstream current-use optical fiber 111. A multiplexing unit 23uw, for multiplexing the supervisory light having wavelength λ_{s0} and the upstream signal light having wavelengths λ_{uw1} to λ_{uwn} , and a demultiplexing unit 13uw, for demultiplexing the supervisory light having wavelength λ_{s0} from the upstream signal light having wavelengths λ_{uw1} to λ_{uwn} , are provided for the upstream current-use optical fiber 112. A multiplexing unit 13dp, for multiplexing the supervisory light having wavelength λ_{s1} and the downstream signal light having wavelengths λ_{dp1} to λ_{dpn} , and a demultiplexing unit 23dp, for demultiplexing the supervisory light having wavelength λ_{s1} from the downstream signal light having wavelengths λ_{dp1} to λ_{dpn} , are provided for the downstream redundant optical fiber 121. A multiplexing unit 23up, for multiplexing the supervisory light having wavelength λ_{s1} and the upstream signal light having wavelengths λ_{up1} to λ_{upn} , and a demultiplexing unit 13up, for demultiplexing the supervisory light having wavelength λ_{s1} from the

upstream signal light having wavelengths λ_{up1} to λ_{upn} , are provided for the upstream redundant optical fiber 122.

When a failure occurs in the current-use optical fiber, the downstream optical signals having wavelengths λ_{dpl} to λ_{dpn} need only be multiplexed in accordance with the select signal received from the supervisory control unit 14, so that these signals can be transmitted along the downstream redundant optical fiber 121 to the individual ONUs 30-1 to 30-n. The optical transmitters 31 of the ONUs 30-1 to 30-n transmit the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , which are to be transferred along the upstream current-use optical fiber 112 at the multiplexing section, and transmits the upstream optical signals having λ_{up1} to λ_{upn} , which are to be transferred along the upstream redundant optical fiber 122. Further, in accordance with a selection signal received from the supervisory control unit 14, the optical receivers 11-1w to 11-nw or 11-1p to 11-np are selected in order to receive the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} or λ_{up1} to λ_{upn} .

In Fig. 8A is shown a wavelength allocation for the second embodiment. Assume that wavelengths λ_{dw1} to λ_{dwn} are defined as 1570.4 to 1582.9 nm, wavelengths λ_{uw1} to λ_{uwn} are defined as 1546.3 to 1561.4 nm, wavelength λ_{dpl} to λ_{dpn} are defined as 1590.4 to 1603.2 nm, and wavelengths λ_{up1} to λ_{upn} are defined as 1530.3 to 1542.1 nm. Further, assume that wavelength λ_{s0} is defined as 1510 nm and

wavelength λ_{s1} is defined as 1520 nm, so that a different range can be allocated for each wavelength.

Another example for the wavelength allocation is shown in Fig. 8B. Assume that wavelengths λ_{dw1} to λ_{dwn} are defined
5 as 1570.4 to 1582.9 nm, wavelengths λ_{uw1} to λ_{uwn} are defined as 1546.3 to 1561.3 nm, wavelengths λ_{dp1} to λ_{dpn} are defined as 1571.2 to 1583.7 nm, and wavelengths λ_{up1} to λ_{upn} are defined as 1550.1 to 1562.2 nm. Further, assume that wavelength λ_{s0} is defined as 1510 nm and wavelength λ_{s1}
10 is defined as 1510 nm, so that a wavelength band may overlap for the current-use system and for the reserve system, or the same wavelength may be allocated as λ_{s0} and λ_{s1} .

In the examples in both Fig. 8A and Fig. 8B, as well as in the first embodiment, the wavelength difference $\Delta\lambda$
15 between the current-use system and the reserve system is designated in accordance with the locations of the ports of the AWG 22. It should be noted that when the wavelength bands for the current-use system and for the reserve system overlap, and when a failure has occurred in an optical
20 transmission/reception unit, not only the pertinent optical transmission/reception unit, but all the other optical transmitter/receiver should be replaced.

According to this embodiment, since the downstream AWG 22d and the upstream AWG 22u are provided independently,
25 unlike in the first embodiment, the difference between the wavelengths of the downstream optical signal and the upstream optical signal need not be set as an aFSR, and

an arbitrary difference can be designated. Thus, switching between the current-use system and the reserve system can be passively performed by using two AWGs, with the dual optical fiber strands being provided for the multiplexing section.

(Current-use and reserve-use switching configuration employing optical switches)

In Fig. 9 is shown a current-use and a reserve-use switching configuration, according to the second embodiment, that employs optical switches. The OSU 10 also includes: an optical switch 16dw, used to set ON or OFF for the output of the downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} to the downstream current-use optical fiber 111; and an optical switch 16uw, used to set to ON or OFF the output, to the upstream current-use demultiplexing unit 12uw, of the upstream optical signals that have wavelengths λ_{uw1} to λ_{uwn} and have been received along the upstream current-use optical fiber 112. The OSU 10 further includes: an optical switch 16dp, used to set to ON or OFF the output, to the downstream redundant optical fiber 121, of the down optical signals having wavelengths λ_{dp1} to λ_{dpn} ; and an optical switch 16up, used to set to ON or OFF the output, to the upstream reserve demultiplexing unit 12up, of the upstream optical signals that have wavelengths λ_{up1} to λ_{upn} and are received along the upstream redundant optical fiber 122.

In this embodiment, for a transmission along the

downstream current-use optical fiber 111, the optical switch 16dw is set to the ON state while the optical switch 16dp is set to the OFF state, and for a transmission along the downstream redundant optical fiber 112, the optical switch 16dw is set to the OFF state while the optical switch 16dp is set to the ON state. Further, when the upstream current-use optical fiber 112 is to be selected to receive the upstream optical signals transmitted by the ONUs 30, the optical switch 16uw is set to the ON state and the optical switch 16up is set to the OFF state. When the upstream redundant optical fiber 122 is to be selected to receive the upstream optical signals transmitted by the ONUs 30, the optical switch 16uw is set to the OFF state and the optical switch 16up is set to the ON state.

When a failure occurs in the downstream current-use optical fiber 111, the states of the optical switches 16dw and 16dp are changed in accordance with a selection signal received from the supervisory control unit 14, so that the downstream optical signals addressed to the ONUs 30 are transmitted along the downstream redundant optical fiber 112. The optical transmitter/receiver 31 of the ONUs 30 transmit the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , which are to be transferred along the upstream current-use optical fiber 112 at the multiplexing section, and the upstream optical signals having wavelengths λ_{up1} to λ_{upn} , which are to be transferred along the upstream redundant optical fiber 122. Further,

the states of the optical switches 16uw and 16up are changed in accordance with a selection signal received from the supervisory control unit 14, and the upstream optical signals having wavelengths λ_{u1} to λ_{un} , or λ_{up1} to λ_{upn} , are received.

Further, when a failure occurs in one of the current-use optical transmitter/receiver 11-1w to 11-nw of the OSU 10, the state of the optical switch 16 is changed in accordance with a selection signal from the supervisory control unit 14, and the reserve optical transmitter/receiver 11-1p to 11-np can be selected. The configuration wherein the W-MULDEM unit 20 is constituted only by passive parts need only be provided to switch between the current-use system and the reserve system for the optical fibers at the multiplexing section and for the optical transmitter/receiver of the OSU 10.

(Configuration for current-use and reserve-use switching by employing optical switches and by performing a loopback process)

In Fig. 10 is shown a configuration that performs current-use and reverse-use switching by employing the optical switches used for the second embodiment, and by performing a loopback process. In the configuration in the above example, each of the ONUs 30 includes a light source, modulates an optical carrier emitted by the light source, and generates an upstream optical signal. However, in the following example, each of the ONUs 30 receives

an optical carrier from the OSU 10, modulates the optical carrier, and returns the result as an upstream optical signal. The configuration as in the example shown in Fig. 9 is also employed for an optical wavelength division multiplexing access system according to this example, except for additionally providing an arrangement wherein the OSU 10 supplies to each of the ONUs 30 an optical carrier for an upstream signal.

The OSU 10 additionally includes: an optical carrier supply module (OCSM) 19w, which collectively generates optical carriers, used for upstream optical signals, that have wavelengths λ_{uw1} to λ_{uwn} and are to be transferred to the ONUs 30 along the downstream current-use optical fiber 111; a WDM coupler 13cw, which multiplexes the optical carriers for upstream signals and transmits the resultant carrier to the downstream current-use optical fiber 111; an optical carrier supply module (OCSM) 19p, which collectively generates optical carriers, used for upstream signals, that have wavelengths λ_{up1} to λ_{upn} and are to be supplied to the ONUs 30 along the redundant optical fiber 121; and a WDM coupler 13cp, which multiplexes the optical carriers for upstream signals and transmits the resultant carrier to the downstream redundant optical fiber 121.

The optical carrier supply modules (OCSMs) can be a plurality of single-wavelength laser beam sources, the wavelengths of which differ, and a multi-wavelength light

source that is constituted by a light multiplexing unit that multiplexes the output beams or a multi-wavelength collective oscillation light source described in document 1.

5 The OSU 10 also includes: a WDM coupler 13cw, which multiplexes the optical carriers for upstream signals, and have wavelengths λ_{uw1} to λ_{uwn} ; and transmits the resultant carrier to the downstream current-use optical fiber 111; and a WDM coupler 13cp, which multiplexes the
10 optical carriers for upstream signals, and have wavelengths λ_{up1} to λ_{upn} , and transmits the resultant carrier to the downstream redundant optical fiber 121. An AWG 17c includes: two ports W and P, which are connected to the downstream current-use optical fiber 111 and the downstream
15 redundant optical fiber 121 extended at the multiplexing section; and n ports #1 to #n, which are connected to tunable light sources 19-1 to 19-n and which output optical carriers for upstream signals.

20 The optical transmission/reception circuits 31 of the ONUs 30-1 to 30-n include optical modulators, which modulate the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} and are supplied by the OSU 10, and which obtain upstream signals.

25 The AWG 22d of the W-MULDEM unit 20 receives, at port W along the downstream current-use optical fiber 111, the downstream optical signals that have wavelengths λ_{dw1} to λ_{dwn} and the optical carriers for upstream signals that

have wavelengths λ_{uw1} to λ_{uwn} , and demultiplexes these signals to the ports #1 to #n corresponding to the ONUs 30. Also, the AWG 22d receives, at port P along the downstream redundant optical fiber 121, the downstream optical signals having wavelengths λ_{dp1} to λ_{dpn} and the optical carriers for upstream signals that have wavelengths λ_{up1} to λ_{upn} , and demultiplexes these signals to the ports #1 to #n corresponding to the ONUs 30.

In this embodiment, when the current-use optical fiber 101 is to be employed, the optical transmitter/receiver 18-1 to 18-n and the tunable light sources 19-1 to 19-n transmit the downstream optical signals that have wavelengths λ_{dw1} to λ_{dwn} and the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} . The downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} are multiplexed by the downstream AWG 17d, and the resultant signal is output to the downstream current-use optical fiber 111. The optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} are multiplexed by the AWG 17c, and the resultant carrier is output by the WDM coupler 13cw to the downstream current-use optical fiber 111. The optical carriers for upstream signals are modulated by the optical modulators of the ONUs 30, and upstream signals that are obtained are transmitted to the W-MULDEM unit 20.

When a failure occurs in the downstream current-use optical fiber 111, the states of the optical switches 16dw

and 16dp are changed in accordance with a selection signal received from the supervisory control unit 14, and the downstream optical signals to be transferred to the ONUs 30 are transmitted along the downstream redundant optical fiber 112. Further, the optical transmitter/receiver 31 of the ONUs 30 transmit the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , which are to be transferred along the upstream current-use optical fiber 112 at the multiplexing section, and the upstream optical signals having wavelengths λ_{up1} to λ_{upn} , which are to be transferred along the upstream redundant optical fiber 122. Then, the states of the optical switches 16uw and 16up are changed in accordance with a selection signal transmitted by the supervisory control unit 14, and the upstream optical signals having wavelengths λ_{u1} to λ_{un} , or λ_{up1} to λ_{upn} , are received.

In addition, when a failure has occurred in one of the current-use optical transmitter/receiver 11-1w to 11-nw of the OSU 10, the state of the optical switch 16 is changed in accordance with the select signal from the supervisory control unit 14, and the reserve optical transmitter/receiver 11-1p to 11-np can be selected. The configuration wherein the W-MULDEM unit 20 is constituted only by passive parts need only be provided to switch between the current-use system and the reserve system for the optical fibers at the multiplexing section, and for the optical transmitter/receiver of the OSU 10.

(Configuration for current-use and reserve-use switching by varying a wavelength)

In Fig. 11 is shown the configuration according to the second embodiment in which the wavelengths of the optical transmitter/receiver are changed to perform the current-use and reserve-use switching. The OSU 10 includes: optical transmitter/receiver 18-1 to 18-n, which transmit downstream optical signals by selecting either wavelength λ_{dwk} or λ_{dpk} (k is an integer of one or greater to n or smaller; $\lambda_{dpk} = \lambda_{dwk} + \Delta\lambda_d$ ($\Delta\lambda_d$ is a constant value)) from among wavelengths λ_{dw1} to λ_{dwn} and wavelengths λ_{dp1} to λ_{dpn} that are consonant with the individual ONUs 30, and which receive the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , or λ_{up1} to λ_{upn} ; and the downstream AWG 17d and the upstream AWG 17u.

The downstream AWG 17d includes: two ports W and P, which are connected to the downstream current-use optical fiber 111 and the downstream redundant optical fiber 121 at the multiplexing section; and n ports #1 to # n , which are connected to the output ports of the optical transmitter/receiver 18-1 to 18-n. The upstream AWG 17u includes: n ports #1 to # n , which are connected to the output ports of the optical transmitter/receiver 18-1 to 18-n; and two ports W and P, which are connected to the upstream current-use optical fiber 112 and the upstream redundant optical fiber 122 at the multiplexing section.

The ONUs 30-1 to 30- n includes: optical

transmitter/receiver 31, which transmit the upstream optical signals by selecting either wavelength λ_{upk} or λ_{upk} (k is an integer of one or greater to n or smaller; $\lambda_{upk} = \lambda_{uwk} + \Delta\lambda_u$ ($\Delta\lambda_u$ is a constant value)) from among
5 wavelengths λ_{uw1} to λ_{uwn} and wavelengths λ_{up1} to λ_{upn} .

For transmission along the downstream current-use optical fiber 111, the optical transmitter/receiver 18-1 to 18- n of the OSU 10 select and transmit the downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} , and the
10 downstream AWG 17d multiplexes these signals and transmits the resultant signal along the downstream current-use optical fiber 111. In the W-MULDEM unit 20, the downstream AWG 22d demultiplexes the downstream optical signal, and the optical transmitter/receiver of the individual ONUs
15 30 receive the demultiplexed signals. For transmission along the upstream current-use optical fiber 112, the optical transmitter/receiver 31 of the ONUs 30 select and transmit the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , and in the W-MULDEM unit 20, the AWG 22u
20 multiplexes these signals and transmits the resultant signal to the upstream current-use optical fiber 112. The AWG 17u of the OSU 10 demultiplexes the upstream optical signal, and the optical transmitter/receiver 18-1 to 18- n of the OSU 10 receive the demultiplexed signals.

25 When a failure occurs in the current-use optical fiber, the wavelengths selected by the optical transmitter/receiver 18-1 to 18- n of the OSU 10 are changed

to λ_{dp1} to λ_{dpn} , in accordance with a selection signal obtained from the supervisory control unit 14. Then, the downstream optical signals are output to port P of the downstream AWG 17d for transfer along the downstream
5 redundant optical fiber 121. In the same manner, the wavelengths of the upstream optical signals, which are to be transmitted by the optical transmitter/receiver 31 of the ONUs 30, are also changed to λ_{up1} to λ_{upn} for transfer along the upstream redundant optical fiber 122.

10 As means for transmitting a select signal from the supervisory control unit 14 to the optical transmitter/receiver 31 of the ONUs 30, first, the select signal is transmitted by the supervisory control unit 14 to the optical transmitter/receiver 18-1 to 18-n of the
15 OSU 10. The optical transmitter/receiver 18-1 to 18-n insert the select signal into the unused frames of the downstream signals, and transmit the obtained signals to the optical transmitter/receiver 31 of the ONUs 30. It should be noted that a failure occurring in the optical
20 transmitter/receiver 18-1 to 18-n can be coped with by providing the dual structure for the optical transmitter/receiver, and by employing the optical switches that select the current-use system or the reserve system.

(Configuration for current-use and reserve-use
25 switching by varying wavelengths and by performing a loopback process)

In Fig. 12 is shown a configuration according to the

second embodiment wherein the wavelengths of the optical transmitter/receiver are changed and the loopback process is performed for the current-use and reserve-use switching.

According to the configuration in the above example, the ONUs 30 include light sources, and modulate optical carriers emitted by the light sources and generate upstream optical signals. In the following example, the OSU 10 supplies optical carriers to the ONUs 30, and the individual ONUs 30 modulate the received optical carriers and return the obtained carriers as upstream optical signals. The configuration for the example in Fig. 11 is also employed for an optical wavelength division multiplex access system for this example, except for additionally providing an arrangement for supplying optical carriers, used for upstream signals, by the OSU 10 to the ONUs 30.

The OSU 10 includes: tunable light sources 19-1 to 19-n, which select and output an optical carrier, used for an upstream signal, that has wavelength λ_{uwk} (k is an integer of 1 or greater to n or smaller) or wavelength λ_{upk} ($= \lambda_{uwk} + \Delta\lambda_u$; k is an integer of one or greater to n or smaller), so as to supply the optical carrier to the ONUs 30 along the downstream current-use optical fiber 111; and the AWG 17c, which multiplexes the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} or λ_{up1} to λ_{upn} and have been received from the tunable light sources 19-1 to 19-n, and outputs the resultant signal to both the downstream current-use optical fiber 111 and

the downstream redundant optical fiber 121.

The OSU 10 also includes: the WDM coupler 13cw, which multiplexes the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} and transmits the resultant carrier to the downstream current-use optical fiber 111; and a WDM coupler 13cp, which multiplexes the optical carriers for upstream signals that have wavelengths λ_{up1} to λ_{upn} and transmits the resultant carrier to the downstream redundant optical fiber 121. The AWG 17c includes: two ports W and P, which are connected to the downstream current-use optical fiber 111 and the downstream redundant optical fiber 121 at the multiplexing section; and n ports #1 to #n, which are connected to the tunable light sources 19-1 to 19-n that output the optical carriers for upstream signals.

The optical transmission/reception circuits 31 of the ONUs 30-1 to 30-n include optical modulators, which modulate the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} or λ_{up1} to λ_{upn} and are supplied by the OSU 10 and obtain upstream signals.

The AWG 22d of the W-MULDEM unit 20 receives, at the port W along the downstream current-use optical fiber 111, the downstream optical signals that have wavelengths λ_{dw1} to λ_{dwn} and the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} , and demultiplexes these signals to the ports #1 to #n that correspond to the ONUs 30. Furthermore, the AWG 22d receives, at the port P along

the downstream redundant optical fiber 121, the downstream optical signals that have wavelengths λ_{dp1} to λ_{dpn} , and the optical carriers for upstream signals that have wavelengths λ_{up1} to λ_{upn} , and sorts these signals to the ports #1 to #n that correspond to the ONUs 30.

In this embodiment, when the current-use optical fiber 101 is employed, the optical transmitter/receiver 18-1 to 18-n and the tunable light sources 19-1 to 19-n transmit the downstream optical signals that have wavelengths λ_{dw1} to λ_{dwn} and the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} . The downstream AWG 17d multiplexes the downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} , and outputs the resultant signal to the downstream current-use optical fiber 111. The AWG 17c multiplexes the optical carriers for upstream signals that have wavelengths λ_{uw1} to λ_{uwn} , and the WDM coupler 13cw outputs the resultant signal to the downstream current-use optical fiber 111. The light modulators of the ONUs 30 modulate the optical carriers for upstream signals and output the obtained upstream signals to the W-MULDEM unit 20.

When a failure occurs in the current-use optical fiber, a select signal is transmitted from the supervisory control unit 14 to the optical transmitter/receiver 18-1 to 18-n and the tunable light sources 19-1 to 19-n. The downstream optical signals that have wavelengths λ_{dp1} to λ_{dpn} and the optical carriers for upstream signals having

wavelengths λ_{up1} to λ_{upn} are changed, so that the optical fiber to be used is changed to the redundant optical fiber.

Furthermore, a failure that occurs in the optical transmitter/receiver 18-1 to 18-n can be coped with by providing a dual structure for the optical transmitter/receiver, and by employing the optical switches that select either the current-use system or the reserve system.

[Third Embodiment]

In Fig. 13 is shown an optical wavelength division multiplexing access system according to a third embodiment of the present invention. Since multiplexing sections extended between an OSU 10 and ONUs 30-1 to 30-n and extended between the OSU 10 and a W-MULDEM unit 20, and access sections between the individual ONUs 30 to 30-n and the W-MULDEM unit 20 are the same as those for the second embodiment, only the configuration of the W-MULDEM unit 20 is shown here.

The downstream AWG 22d of the second embodiment has a configuration wherein the current-use downstream optical signal received at the port W and the reserve downstream optical signal received at the port P are distributed to the ports #1 to #n. In this embodiment, a special downstream current-use multiplexing/demultiplexing unit 23dw and a special reserve multiplexing/demultiplexing unit 23dp are employed. Further, in the second embodiment, the upstream AWG 22u has a configuration wherein the current-use

downstream optical signals received at the ports #1 to #n are merged at the port W, and the reserve downstream optical signals are merged at the port P. In this embodiment, a special upstream current-use

5 multiplexing/demultiplexing unit 23uw and a special upstream reserve multiplexing/demultiplexing unit 23up are employed.

So long as multiplexing or demultiplexing for the one-to-n correspondence can be performed, the downstream
10 current-use multiplexing/demultiplexing unit 23dw, the downstream reserve multiplexing/demultiplexing unit 23dp, the upstream current-use multiplexing/demultiplexing unit 23uw and the upstream reserve multiplexing/demultiplexing unit 23up need not always be AWGs.

15 Downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} , received along a downstream current-use optical fiber 111, are sorted by the downstream current-use multiplexing/demultiplexing unit 23dw. Downstream optical signals having wavelengths λ_{dp1} to λ_{dpn} , received
20 along a downstream redundant optical fiber 121, are sorted by the downstream reserve multiplexing/demultiplexing unit 23dp. Wavelength group filters 24-1d to 24-nd transmit, to downstream optical fibers corresponding to the ONUs 30, the downstream optical signals having wavelengths λ_{dw1}
25 to λ_{dwn} , or λ_{dp1} to λ_{dpn} .

Upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , or λ_{up1} to λ_{upn} , received from the optical fibers

corresponding to the ONUs 30, are transmitted through wavelength group filters 24-1u to 23-nu to corresponding ports #1 to #n of the upstream current-use multiplexing/demultiplexing unit 23uw or the upstream reserve multiplexing/demultiplexing unit 23up. The upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , which are received by the upstream current-use multiplexing/demultiplexing unit 23uw, are multiplexed, and the resultant signal is transmitted to the upstream current-use optical fiber 112. The upstream optical signals having wavelengths λ_{up1} to λ_{upn} , which are received by the upstream reserve multiplexing/demultiplexing unit 23up, are multiplexed, and the resultant signal is transmitted to the upstream redundant optical fiber 122.

In Fig. 14A are shown example wavelength allocations for the ports W and P and the ports #1 to #n of each multiplexing/demultiplexing unit. According to the configuration for this embodiment, the downstream current-use multiplexing/demultiplexing unit 23dw, the downstream reserve multiplexing/demultiplexing unit 23dp, the upstream current-use multiplexing/demultiplexing unit 23uw and the upstream reserve multiplexing/demultiplexing unit 23up are provided independently, and the wavelength group filters 24-1d to 24-nd multiplex the current-use and reserve signals, while the wavelength group filters 24-1u to 24-nu demultiplex the current-use signals from the reserve use signals. Therefore, the downstream

current-use optical signals having wavelengths λ_{dw1} to λ_{dwn} and the downstream reserve optical signals having wavelengths λ_{dp1} to λ_{dpn} belong to different bands, and the upstream current-use optical signals having wavelengths λ_{uw1} to λ_{uwn} and the upstream reserve optical signals having wavelengths λ_{up1} to λ_{upn} belong to different bands.

However, since the downstream optical signals and the upstream optical signals are independent of each other, the wavelengths can be equalized for the upstream current-use optical signals, for example, and the downstream reserve optical signals, as is shown in Fig. 14B. Furthermore, as is shown in Fig. 14C, the wavelengths can be equalized for the downstream current-use optical signals, for example, and the upstream reserve optical signals, and for the upstream current-use optical signals and the downstream reserve optical signals. As a result, switching between the current-use system and the reserve system can be passively performed by using four multiplexing/demultiplexing units, while a dual stranded optical fiber is obtained at the multiplexing section.

Specifically, for the transmission of downstream optical signals along the downstream current-use optical fiber 111 to the ONUs 30-1 to 30-n, the OSU 10 need only multiplex the downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} that correspond to the individual ONUs 30, and for the transmission along the downstream redundant optical fiber 121, need only multiplex the downstream

optical signals having wavelengths λ_{dp1} to λ_{dpn} that correspond to the ONUs 30. On the other hand, for the transmission of upstream optical signals along the upstream current-use optical fiber 112 at the multiplexing section, the ONUs 30-1 to 30-n need only transmit the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , and for the transmission along the upstream redundant optical fiber 122, need only transmit the upstream optical signals having wavelengths λ_{up1} to λ_{upn} . Using this wavelength selection, the W-MULDEM unit 20 can passively switch between the current-use system and the reserve system.

[Fourth Embodiment]

According to this embodiment, the ONUs provided for the configuration in the third embodiment, shown in Fig. 13, are divided into two groups, #1 to #k and #k+1 to #n, and further, the downstream optical signals are divided into two wavelength groups λ_{d1} to λ_{dk} and λ_{dk+1} to λ_{dn} .

At this time, the wavelengths λ_{d1} to λ_{dk} for the current use and the wavelengths λ_{dk+1} to λ_{dn} as reserves are allocated to the ONUs #1 to #k, and the wavelengths λ_{dk+1} to λ_{dn} for the current use and the wavelengths λ_{d1} to λ_{dk} as reserves are allocated to the ONUs #k+1 to #n. The upstream optical signals are also divided into two wavelength groups, λ_{u1} to λ_{uk} and λ_{uk+1} to λ_{un} . At this time, the wavelengths λ_{u1} to λ_{uk} for the current use and the wavelengths λ_{uk+1} to λ_{un} for the reserves are allocated to the ONUs #1 to #k, and the wavelengths λ_{uk+1} to λ_{un} for the current use

and the wavelengths λ_{u1} to λ_{uk} for the reserves are allocated to the ONUs # $k+1$ to # n .

In Fig. 15A is shown an example wavelength allocation for the ports W and P and the ports #1 to #64 when $n = 64$ and $k = 32$. Specifically, the downstream current-use multiplexing/demultiplexing unit 23dw demultiplexes the downstream optical signals having wavelengths λ_{d1} to λ_{d32} and wavelengths λ_{d33} to λ_{d64} and demultiplexes them to the respective ports #1 to #64, and the downstream reserve multiplexing/demultiplexing unit 23dp demultiplexes the downstream optical signals having wavelengths λ_{d33} to λ_{d64} and wavelengths λ_{d1} to λ_{d32} and demultiplexes them to the respective ports #1 to #64. Then, wavelength group filters 24-1d to 24-nd couple the wavelength group λ_{d1} to λ_{d32} with the wavelength group λ_{d33} to λ_{d64} .

The upstream current-use multiplexing/demultiplexing unit 23uw multiplexes the upstream optical signals having wavelengths λ_{u1} to λ_{u32} and wavelengths λ_{u33} to λ_{u64} , which are received at the ports #1 to #64, and the upstream reserve multiplexing/demultiplexing unit 23up multiplexes the upstream optical signals having wavelengths λ_{u33} to λ_{u64} and wavelengths λ_{u1} to λ_{u32} , which are received at the ports #1 to #64. Then, the wavelength group filters 24-1n to 24-nu couple the wavelength group λ_{u1} to λ_{u32} with the wavelength group λ_{u33} to λ_{u64} .

Since the downstream optical signals (wavelengths λ_{d1} to λ_{dn}) and the upstream optical signals (wavelengths

λ_{d1} to λ_{dn}) are independent of each other, these signals may be set in different bands, as shown in Fig. 15B, or may be set in the same band, as is shown in Fig. 15C. In the second case, n wavelengths can be designated for the current-use system and the reserve system that correspond to n ONUs. Further, so long as multiplexing and demultiplexing can be performed with a one-to- n correspondence, the downstream current-use multiplexing/demultiplexing unit 23dw, the downstream reserve multiplexing/demultiplexing unit 23dp, the upstream current-use multiplexing/demultiplexing unit 23uw and the upstream reserve multiplexing/demultiplexing unit up need not always be AWGs.

[Fifth Embodiment]

In Fig. 16 is shown an optical wavelength division multiplexing access system according to a fifth embodiment of the present invention. Since the optical wavelength division multiplexing access system in this embodiment is the same as that for the second embodiment shown in Fig. 12, except for a W-MULDEM unit 20, only the configuration for the W-MULDEM unit 20 is shown here.

The W-MULDEM unit 20 includes: an optical carrier AWG 22c and wavelength group filters 25w, 25p and 25-1d to 25-nd, in addition to the downstream AWG 22d and the upstream AWG 22u for the second embodiment in Fig. 7. The wavelength group filter 25w demultiplexes downstream optical signals having wavelengths λ_{d1} to λ_{dn} , which are

received, along a downstream current-use optical fiber 111, from optical carriers having wavelengths λ_{u1} to λ_{un} , which are used for upstream signals, and respectively transmits the downstream optical signals and the optical carriers to the port W of the downstream AWG 22d and the port W of the optical carrier AWG 22c. The wavelength group filter 25p demultiplexes downstream optical signals having wavelengths λ_{d2} ($\lambda_{d1} + \Delta\lambda_d$) to λ_{dn+1} ($\lambda_{dn} + \Delta\lambda_d$), which are received along a downstream redundant optical fiber 121, from optical carriers having wavelengths λ_{u2} ($\lambda_{u1} + \Delta\lambda_u$) to λ_{un+1} ($\lambda_{un} + \Delta\lambda_u$), which are used for upstream signals, and respectively transmits the downstream optical signals and the optical carriers to the port P of the downstream AWG 22d and to the port P of the optical carrier AWG 22c.

The optical carrier AWG 22c demultiplexes the optical carriers having wavelengths λ_{u1} to λ_{un} , which are used for upstream signals, to the ports #1 to #n that correspond to the individual ONUs. The wavelength group filters 25-1d to 25-nd multiplex the downstream optical signals, demultiplexed by the downstream AWG 22d, with the optical carriers for upstream signals that are demultiplexed by the upstream signal optical carrier AWG 22c, and transmits the obtained signals to the downstream optical fibers that correspond to the individual ONUs.

The wavelengths are allocated, as shown in Figs. 8A and 8B, to the ports W and P and the ports #1 to #n of

the downstream AWG 22d, the upstream AWG 22u and the optical carrier AWG 22c. In this embodiment, since the downstream optical signals and the upstream optical signals (optical carriers for upstream signals) should be set to different bands, the wavelengths can not be equalized for the downstream optical signals and the upstream optical signals.

[Sixth Embodiment]

In Fig. 17 is shown an optical wavelength division multiplexing access system according to a sixth embodiment of the present invention. Since the optical wavelength division multiplexing access system in this embodiment is the same as that for the second embodiment shown in Fig. 12, except for a W-MULDEM unit 20 and wavelengths for optical carriers, upstream optical signals and downstream optical signals shown in the drawing, only the configuration of the W-MULDEM unit 20 is shown here.

According to the configuration for the fifth embodiment, the optical carrier AWG 22c demultiplexes both the optical carrier, which is received at the port W for the upstream current-use signal, and the optical carrier, which is received at the port P for the upstream reserve signal, to the ports #1 to #n. In this embodiment, a special current-use optical carrier multiplexing/demultiplexing unit 23cw and a special reserve optical carrier multiplexing/demultiplexing unit 23cp are employed. In addition, according to the configuration for the fifth

embodiment, the downstream AWG 22d demultiplexes both the downstream current-use optical signal received at the port W and the downstream reserve optical signal received at the port P to the ports #1 to #n. In this embodiment,
5 a special downstream current-use multiplexing/demultiplexing unit 23dw and a special downstream reserve multiplexing/demultiplexing unit 23dp are employed. Moreover, according to the configuration for the fifth embodiment, the upstream AWG 22u multiplexes
10 at the port W the downstream current-use optical signals received at the ports #1 to #n, and multiplexes the downstream reserve optical signals at the port P. In this embodiment, a special upstream current-use multiplexing/demultiplexing unit 23uw and a special
15 upstream reserve multiplexing/demultiplexing unit 23up are employed.

A wavelength group filter 25w demultiplexes the downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} , which are received along a downstream current-use optical
20 fiber 111, from the optical carriers having wavelengths λ_{uw1} to λ_{uwn} , which are used for upstream signals, and transmits these signals and carriers to the current-use optical carrier multiplexing/demultiplexing unit 23cw and the downstream current-use multiplexing/demultiplexing
25 unit 23dw. A wavelength group filter 25p demultiplexes the downstream optical signals having wavelengths λ_{d1} to λ_{dn} , which are received along a downstream redundant optical

fiber 121, from optical carriers having wavelengths λ_{up1} to λ_{upn} , which are used for upstream signals, and transmits the signals and carriers to the reserve optical carrier multiplexing/demultiplexing unit 23cp and the downstream reserve multiplexing/demultiplexing unit 23dp.

The current-use optical carrier multiplexing/demultiplexing unit 23cw demultiplexes the optical carriers having wavelengths λ_{uw1} to λ_{uwn} , which are used for upstream signals, and the reserve optical carrier multiplexing/demultiplexing unit 23cp demultiplexes the optical carriers having wavelengths λ_{up1} to λ_{upn} , which are used for upstream signals, and transmits the demultiplexed carriers to the wavelength group filter 25-1d through the wavelength group filters 24-1c (to 24-nc).

The downstream reserve multiplexing/demultiplexing unit 23dw demultiplexes the downstream optical signals having wavelengths λ_{dw1} to λ_{dwn} , and the downstream current multiplexing/demultiplexing unit 23dp demultiplexes the downstream optical signals having wavelengths λ_{dp1} to λ_{dpn} , and transmits the demultiplexed signals to the wavelength group filter 25-1d through the wavelength group filters 24-1d (to 24-nd). The wavelength group filters 25-1d (to 25-nd) transmit, to downstream optical fibers 131 that correspond to the individual ONUs 30, the optical carriers for upstream signals and the downstream signals for current use, or the optical carriers for upstream signals and the downstream optical signals for reserves.

The wavelength group filters 25-1u (to 25-nu) transmit the upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , which are received along upstream optical fibers 132 corresponding to the ONUs 30, to the upstream current-use multiplexing/demultiplexing unit 23uw, and transmit the upstream optical signals having wavelengths λ_{up1} to λ_{upn} to the upstream reserve multiplexing/demultiplexing unit 23up. The upstream current-use multiplexing/demultiplexing unit 23uw multiplexes the received upstream optical signals having wavelengths λ_{uw1} to λ_{uwn} , and transmits the resultant signal to the upstream current-use optical fiber 112. The upstream reserve multiplexing/demultiplexing unit 23up multiplexes the received upstream optical signals having wavelengths λ_{up1} to λ_{upn} , and transmits the resultant signal to the upstream redundant optical fiber 122.

The wavelengths are allocated, as shown in Fig. 14A or Figs. 15A and 15B, to the ports W and P and the ports #1 to #n of the current-use optical carrier multiplexing/demultiplexing unit 23cw, the reserve optical carrier multiplexing/demultiplexing unit 23cp, the downstream current-use multiplexing/demultiplexing unit 23dw, the downstream reserve multiplexing/demultiplexing unit 23dp, the upstream current-use multiplexing/demultiplexing unit 23uw and the upstream reserve multiplexing/demultiplexing unit 23up. In this embodiment, the downstream optical signals and the upstream

optical signals (optical carriers for upstream signals) must be set to different bands. Therefore, unlike shown in Figs. 14B, 14C and 15C, the wavelengths can not be equalized for the optical signals and the upstream optical signals (optical carriers for upstream signals).

[Seventh Embodiment]

An optical wavelength division multiplexing access system according to a seventh embodiment of the present invention is shown in Fig. 18. In this embodiment, a dual structure is provided for the optical fiber at each access section shown in the above described embodiments (hereinafter, the first embodiment shown in Fig. 3 is employed for the explanation). For an ONU 30-2 for which a dual access section is provided, two wavelengths are allocated to downstream current-use optical signals (λ_{dk} , λ_{dk+1}), downstream reserve optical signals ($\lambda_{dk+\Delta\lambda}$, $\lambda_{dk+1+\Delta\lambda}$), upstream current-use optical signals (λ_{uk} , λ_{uk+1}) and the upstream reserve optical signals ($\lambda_{uk+\Delta\lambda}$, $\lambda_{uk+1+\Delta\lambda}$). That is, the same arrangement is provided as when two ONUs that do not have dual structures are employed.

[Eighth Embodiment]

In this embodiment, a dual structure is provided for current-use optical transmitter/receiver 11-1w to 11-nw and reserve optical transmitter/receiver 11-1p to 11-np in an OSU 10. When a failure occurs in the current-use optical fiber and the reserve optical transmitter/receiver 11-1p to 11-np, the redundant optical fiber and the reserve

optical transmitter/receiver in a reserve system are employed to continue the operation. When a failure occurs in the redundant optical fiber and the current-use optical transmitter/receiver 11-1w to 11-nw, the current-use optical fiber and reserve optical transmitter/receiver in the current-use system are employed to continue the operation. In this manner, a redundant structure can be obtained that can cope with a double failure in the optical fiber and the optical transmitter/receiver.

[Ninth Embodiment]

According to the configuration for the above embodiments, the supervisory light has been employed to supervise the current-use optical fiber and the redundant optical fiber. In this embodiment, instead of using supervisory light, a cutoff of the transmission of upstream optical signals by optical transmitter/receiver of an OSU 10 is detected, so that shearing of an optical fiber is determined. An optical wavelength division multiplexing access system according to a ninth embodiment of the present invention is shown in Fig. 19. As is shown in Fig. 19, the configuration for the system in the second embodiment is also employed for the optical wavelength division multiplexing access system for this embodiment, except that the light source 15, for emitting supervisory light, and the multiplexing/demultiplexing unit 13, for transmitting the supervisory light to each optical fiber by performing the multiplexing or demultiplexing process,

are not included.

The OSU 10 further includes: current-use optical transmitter/receiver 11-1w to 11-nw; optical switches 16-1dw to 16-ndw and 16-luw to 16 nuw, used to set ON or
5 OFF for input/output of light; reserve optical transmitter/receiver 11-1w to 1-nw; and optical switches 16-1dp to 16-ndp and 16-lup to 16 nup, used to set ON or OFF for input/output of light.

In this embodiment, when a current-use optical fiber
10 is employed, the optical switches 16-1dw to 16-ndw and 16-1uw to 16-nuw are in the ON state, and the optical switches 16-1dp to 16-ndp and 16-lup to 16-nup are in the OFF state.

When a failure has occurred in the current-use optical fiber, transmission of the upstream optical signals by
15 the optical transmitter/receiver 11-1w to 11-nw is cut off, and a supervisory control unit 14 transmits a select switch to the individual optical switches. When the optical switches 16-1dw to 16-ndw and 16-1uw to 16-nuw are set to the OFF state, and the optical switches 16-1dp to 16-ndp
20 and 16-lup to 16-nup are set to the ON state, the current-use optical fiber can be changed to the redundant optical fiber.

When failures occur in some of the current-use optical transmitter/receiver 11-1w to 11-nw, a selection switch
25 need only be transmitted to the optical switches that correspond to those current-use optical transmitter/receiver 11-1w to 11-nw that have malfunctioned, so that the optical transmitter/receiver can be changed.

As means for collectively detecting a cutoff of the transmission of upstream signals from the ONUs 30, a small number of upstream optical signals obtained by multiplexing are branched at the upstream current-use optical fiber 112 and the redundant optical fiber 122, and are monitored.

The states of the current-use and redundant optical fibers can also be monitored by detecting the presence/absence of optical signals.

With the above described arrangement, the optical fibers to be employed and the current-use system and the reserve system for the optical transmitter/receiver of the OSU 10 can be selected by the W-MULDEM unit 20 that is constituted only by passive parts.

[Tenth Embodiment]

The processing for performing current-use and reserve-use switching is shown in Fig. 20 as a tenth embodiment. Assume that, for example, for the second embodiment in Fig. 7, a failure occurs in the light source 15 that emits supervisory light having wavelengths λ_{s0} and λ_{s1} , or the supervisory monitor control unit 15 that detects the supervisory light having wavelengths λ_{s0} and λ_{s1} . At this time, the following four cases are expected.

(1) A selection signal is to be transmitted when the supervisory light having wavelength λ_{s0} can not be detected, and the supervisory light having wavelength λ_{s1} can be detected.

(2) A selection signal is to be transmitted when

supervisory lights having wavelengths λ_{s0} and λ_{s1} can not be detected, and upstream optical signals cannot be received from the optical receivers of the OSU and can also not be detected.

5 (3) A selection signal is not to be transmitted when the supervisory light having wavelength λ_{s0} can be detected.

 (4) A selection signal is not to be transmitted when supervisory lights having wavelengths λ_{s0} and λ_{s1} can not be detected, and upstream optical signals cannot be received
10 by the optical receivers of the OSU.

 In this manner, when one of the above described failures has occurred, the current-use optical fiber and the redundant optical fiber that is to be used can be switched without halting the communication between the ONUs and
15 the OSU.

[Eleventh Embodiment]

 In the above described embodiments, a star network configuration has been employed wherein one W-MULDEM unit is connected to one OSU. In this embodiment, a bus network
20 configuration is employed wherein a plurality of W-MULDEM units are connected to one OSU. An optical wavelength division multiplexing access system according to an eleventh embodiment of the present invention is shown in Fig. 21. In the optical wavelengths division multiplexing
25 access system of this embodiment, n W-MULDEM units 20-1 to 20-n are connected, by bus wiring, to one OSU 10 along a downstream current-use optical fiber 111 and an upstream

current-use optical fiber 121, and are also connected, by bus wiring opposite the current-use optical fiber, to the OSU 10 along a downstream redundant optical fiber 121 and an upstream redundant optical fiber 122.

5 Each one of W-MULDEM units 20-k (k is an integer of one or greater to n or smaller) includes: a demultiplexing unit 26dw, for demultiplexing downstream optical signals, having wavelengths λ_{kdw1} to λ_{kdown} , which are received along the downstream current-use optical fiber 111; a
10 multiplexing unit 26uw, for multiplexing upstream optical signals, having wavelengths λ_{kuw1} to λ_{kuwn} , to be transferred to the upstream current-use optical fiber 112; a demultiplexing unit 26dp, for demultiplexing downstream optical signals having wavelengths λ_{kdp1} to λ_{kdpn} , which
15 are received along the downstream redundant optical fiber 121; and a multiplexing unit 326up, for multiplexing upstream optical signals having wavelengths λ_{kup1} to λ_{kupn} , which are to be transferred to the upstream redundant optical fiber 122.

20 The W-MULDEM unit 20-k also includes: a demultiplexing unit 23dw, for demultiplexing a current-use supervisory light having wavelength λ_{sk0} that is received along the downstream current-use optical fiber 111; a
25 multiplexing unit 23uw, for multiplexing the current-use supervisory light having wavelength λ_{sk0} that is to be transferred to the upstream current-use optical fiber 112; a demultiplexing unit 23dp, for demultiplexing the reserve

supervisory light having wavelength λ_{sk1} that is received along the downstream redundant optical fiber 121; a multiplexing unit 23up, for multiplexing the reserve supervisory light having wavelength λ_{sk1} that is to be transferred to the upstream redundant optical fiber 122; and a downstream AWG 27d and an upstream AWG 27u.

The downstream optical signals having wavelengths λ_{1dw1} to λ_{1dwn} , λ_{2dw1} to λ_{2dwn} and λ_{ndw1} to λ_{ndwn} , or wavelengths λ_{1dpl} to λ_{1dpn} , λ_{2dpl} to λ_{2dpn} and λ_{ndpl} to λ_{ndpn} , and the upstream optical signals having wavelengths λ_{1uw1} to λ_{1uwn} , λ_{2uw1} to λ_{2uwn} and λ_{nuw1} to λ_{udwn} , or wavelengths λ_{1up1} to λ_{1upn} , λ_{2up1} to λ_{udpn} and λ_{nup1} to λ_{nupn} , are employed to perform communication between ONUs, which are connected to the corresponding W-MULDEM units 20-1 to 20-n, and the OSU 10.

In this embodiment, the downstream optical signals having wavelengths λ_{kdw1} to λ_{kdwn} , which are transmitted by the OSU 10, or the upstream optical signals having wavelengths λ_{kuw1} to λ_{kuwn} , which are transmitted by the ONUs, are multiplexed or demultiplexed by the corresponding W-MULDEM units 20-k. When a failure occurs in an optical fiber extended at each interval, a fiber malfunction interval is detected by using the supervisory lights for λ_{s10} to λ_{sn0} and λ_{s11} to λ_{sn1} , which are output by the OSU 10, and switching can be performed by employing the same switching means as used for the above embodiments.

With this arrangement wherein n W-MULDEM units 20-1

to 20-n are connected by bus wiring to one OSU 10, the current-use system and the reserve system to be used can be switched for the optical fiber and the optical transmitter/receiver of the OSU 10.

5 [Twelfth Embodiment]

 An optical wavelength division multiplexing access system according to a twelfth embodiment of the present invention is shown in Fig. 22. In the optical wavelength division multiplexing access system, when there is a great
10 transmission loss for the optical fiber at the multiplexing section, amplifiers 41-1 to 41-n, for collectively amplifying a plurality of WDM signals, are inserted between an OSU 10 and a W-MULDEM unit 20. Multi-signal amplifiers 42 and 423 may be internally provided for the W-MULDEM
15 unit 20 and the OSU 10.

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